STATUS REPORT ON LIGHT WATER REACTOR ACTIVITY IN ITALY

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ENEA

Report for IAEA -TWG - LWR 11th Meeting
(Vienna, 9-10 June 2004)

1. THE ITALIAN ELECTRICITY MARKET

During 2003 electricity demand reached 319.7 TWh (+2,9% on 2002) and was covered by domestic production allocated for consumption (84.1%, 3.3% on 2002) and by net import/export balance (15.9%, +0.7% on 2002).
In particular thermal production and production from renewables (geothermal, wind, and photovoltaic) grew by 4.7% and 11.4 %, respectively, whereas hydro production declined (-6,4%).
Import of electricity from neighbouring countries had a slight decrease (-0.1%), while the export dropped sharply (+43.8%).
Among the main events that occurred in 2003 in operation and management of Italian power system, it is worth remembering the national blackout of 28 September, which involved an electricity supply failure of 180 TWh.
In the first quarter of 2004, overall electricity demand was up by 1.8% in comparison with the same period of last year.
Table 1 summarizes production data for 2002 and 2003 .

Table1 – Italy Electricity production (TWH)

Production	**2002**	**%**	**2003**	**%**
Thermal	231	74.3	242	75.7
Hydro	47.3	15.2	44.2	13.8
Renewable	6.1	2.0	6.8	2.1
Nuclear	-	-	-	-
Import	51.5	16.6	51.5	16.1
Export	0.5	0.3	0.9	0.2
Electricity consumed by pumping and auxiliary services	24.3	7.8	24.1	7.5
Electricity supplied (losses + consumption)	310.7		319,7	2,9

2. NATIONAL AGENCY FOR NEW TECHNOLOGIES, ENERGY AND THE ENVIRONMENT (ENEA)

ENEA is being reorganized owing to the promulgation of the law by decree of September 3rd 2003 that defines the new goals and related activities of ENEA, and for the first time after the end of nuclear moratorium orders to perform activities in the field of nuclear technology and application In particular the law states that ENEA is responsible for maintaining the scientific and technical knowledge on nuclear energy.
The fields of intervention and research are: energy, environment and innovation.
Rubbia was confirmed chairman of the management board at the beginning of this year.

3 LWR'S R&D ACTIVITIES

3.1 ENEA's activities

The main strategic activities are focused on the topics of transmutation and liquid metal technology (Pb, Pb-Bi): TRADE experiment and preliminary design of Accelerator Driven System.
LWR activities are limited and focused on the development and validation of methods for the integrated system analysis of nuclear plants, and on maintaining the knowledge about the most relevant methods, solutions and themes related to nuclear fission safety and an adequate domestic capability of evaluating accident sequences to support Government in case of emergency originated by a nuclear plant beyond national border.
They are performed within International programmes promoted by EU, USNRC, NEA-OECD and IAEA, and in the framework of specific agreements with CEA and IRSN.
Main topics are:

- Development and validation of stand-alone and integrated codes for severe accident sequences assessment

ENEA is cooperating with IRSN (F) and other research organisations, like GRS, FZK, JRC-Petten, etc, to the preparation/interpretation of Phebus-PF tests and to the development or/and validation of ICARE2 and ASTEC codes.
In particular in the V EU framework programme ENEA participated in the following five projects:

- ECOSTAR (Ex-vessel Core melt and Stabilization Research) aimed at the understanding the complex phenomena in melt release after vessel failure;
- COLOSS (Core Loss during a severe accident) focused on investigation of some core degradation issues and on improving and validation of model implemented in ICARE2;
- PHEBEN2 (Containment thermal-hydraulics and Source Term), whose purpose is to understand and quantify the physical and chemical phenomena underlying the Phebus results, to validate integral codes for LWR severe accident analysis versus available Phebus test data, to propose guidelines for optimum code use for the various applications and, where possible, quantitative information on uncertainties for use in safety margins assessment, risk studies, etc;
- EVITA (European Validation of the Integral code ASTEC)
- THENPHEBISP, which concerns the International Standard Problem n. 46 promoted by the OECD/CSNI on Phebus FPT-1 experiment, and supported by the EU through a Concerted Action.

In VI EU FP ENEA is only participating in a network called SARNET (Severe Accident Research Network of excellence) with other 54 Research organisations. This network is focused on the investigation of specific issues remained where activity is still necessary to further reduce uncertainties that are considered of importance for nuclear safety and to consolidate severe accident management plans.

- Development Innovative components/systems

This activity was stopped at the beginning of 2003 as the domestic research program on innovative safety systems was not refunded by ENEA. Two important results were achieved the development of:

- high pressure steam injector, that is certainly one of the most interesting apparatus for improving the safety. This activity was also performed in the framework of DEEPSSI project (Design and development of a steam generator emergency feedwater passive system for existing and future PWRs using advanced steam injectors) of V EU program
- passive in-pool energy removal system for emergency operation, which mainly consists of two pools, one empty containing the heat exchanger (HX Pool) and the other one (Overall Poll) full of cold water, a pool bottom connecting pipe with a triggering valve that determines the device intervention, and an upper steam duct with an injector installed at the exit inside the Overall pool to improve the pool water mixing and avoiding thermal stratification phenomena. During the normal operation the valve is closed and its opening causes the flooding of the heat exchanger with consequent heat transfer from the primary side to the pool.

- Passive system reliability

ENEA, first within its domestic program on innovative safety systems in collaboration with Pisa University and Polytechnic of Milano and then within the RMPS[1] project of the V EU framework program on nuclear fission, has developed a methodology for reliability assessment of passive systems. This work will continue within the CRP of IAEA on "Natural Circulation Phenomena, Modelling and Reliability of Passive Systems that utilize natural circulation".

- Innovative plant and generation IV

ENEA is participating in the MICHELANGELO Network (MICANET), aimed at elaborating a European R&D strategy corresponding to the actual needs of industry for facing more and more stringent challenges of competitiveness and sustainability and at developing a strong European partnership with the U.S. initiative "GENERATION IV" in order to obtain a benefit from this initiative for Europe.
Generation IV, initially started as a US initiative, has become an international R&D programme with the objective of developing nuclear energy systems to be ready for deployment in 2030 and addressing satisfactorily nuclear safety, sustainability issues and public concern.
ENEA is indirectly participating in this initiative, contrary to France, Switzerland and England, because CCE has decided to enter Generation IV in the framework of a co-operative agreement with the US Department of Energy and to contribute to the research on future nuclear systems with the JRC activities and with the activities of the Member States participating in the future RTD Framework Programmes. Thanks to this agreement ENEA has access to all the documentation produced.

3.2 Agency for Protection of the Environment and for Technical Services(APAT) activities

APAT[2], which has replaced ANPA (the previous agency for environmental protection acting as Regulatory Board in the nuclear field) since October 2002, is participating in international initiatives, promoted by NEA-OECD or in the framework bilateral agreement with US Nuclear Regulatory Body.

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[1] Reliability Methods for Passive Safety functions

[2] The statute of APAT was approved By the Council of Ministers on August 2nd and published in a Sept 21st decree

Besides participating in activities of OECD-CSNI (Committee on Safety of Nuclear Installations) and its working groups, e.g. CSNI-WGRISK, APAT is involved in the SETH program that foresees the utilization of experimental facilities of PSI (PANDA) and Framatome Nuclear Power Plant GmbH (PKL) for investigating issues relevant for accident prevention and management: countermeasures for boron dilution accidents and loss of heat removal under shut-down conditions and gas flow distributions relevant for reactor containment.
The bilateral agreement with USNRC, which expired in 2003 and is being renewed, concerns researches on probabilistic analysis, thermal-hydraulics and severe accidents matters, besides general obligations about mutual co-operation and information.

3.3 University activities

IRIS design

Since 1999, Italian research institutions (Polytechnic of Milano, University of Pisa, Polytechnic of Torino and University of Roma "La Sapienza") have been engaged in an international research and development activity devoted to the study of an innovative integral nuclear reactor, named IRIS (*International Reactor Innovative and Secure*).
The activity begun in the context of a NERI (Nuclear Energy Renaissance Initiative) research programme, supported by the USA Department of Energy (DOE).
Up to now, 21 organizations from 10 different countries have been developed the IRIS R&D program: universities (MIT, Tokyo Institute of Technology, Zagreb University and the four Italian Universities previously mentioned), industries (Westinghouse –leader–, Ansaldo, Ansaldo-Camozzi, Bechtel, BNFL, ENSA, Nuclep, OKBM), research centres (CNEN-Brazil, ININ-Mexico, Lithuanian Energy Institute, Oak Ridge Nat. Lab.) and utilities (Eletronuclear-Brazil, Tenessee Valley Authority).
IRIS is currently undergoing a pre-licensing process with the U.S. Nuclear Regulatory Commission (NRC), which started late in 2002. Design certification is scheduled for a 2008 - 2010 timeframe, with First-of-a-kind deployment in 2012 - 2015.
Moreover, IRIS is also one of the reactor types being considered by three U.S. utilities for the Early Site Permit studies, sponsored by the U.S. Department of Energy.
The key points of the study refer to a novel LWR with a modular, integral primary system configuration, designed to meet four requirements: enhanced safety, improved economics, proliferation resistance and waste minimisation. Its main features are: medium power (up to 335 MWe/module); a simplified compact design where the primary vessel houses steam generators, pressuriser and pumps; a novel, extremely effective safety approach; and, optimised maintenance with intervals of at least 4 years.
IRIS philosophy is based on "Safety by Design". The choice of an integral configuration is such that a variety of accidents are either eliminated or their consequences and/or probability of occurring or greatly reduced by design (i.e., with no intervention of either active or passive systems). In fact 88% of Class IV accidents (the ones with the possibility for radiation release) are either outright eliminated or downgraded. A simpler, more economical design can be obtained: for example IRIS does not need an emergency core cooling injection system, because the design is such as to guarantee core coverage under all design accidents. Simplified passive systems are featured for those few accidents not affected by the safety by design.
The core is an evolutionary design initially based on conventional UO_2 fuel enriched to 4.95%. Refueling intervals up to 4 years are possible. The reactor is designed to accommodate, without modification, a variety of core designs to keep up with technology advances. Future core designs will include higher enriched UO_2 fuel and the capability to use MOX; both will deliver higher burn-up rates and enhanced fuel cycle economics.
A significant effort is being produced to reduce maintenance shutdowns intervals to at least 48 months, to match the capability of 4 years between refuelings. The reduction in the O&M cost

versus current LWRs is projected to be of about 20% due to the increased capacity factor, reduced forced outages and reduction in staff personnel.
The main research activities in charge of the Italian institutions refer to the following items:
-Risk-informed approach (PSA analyses) to the design and licensing process, supporting the implementation of the "safety-by-design" concept;
-Steam Generator modules with non-conventional configuration for LWRs (helical-coil tube bundles, boiling inside the tubes with superheating, part of the Emergency Heat Removal passive safety System); different phenomena and aspects are being investigated: thermal-hydraulics (including CFD analysis), thermo-mechanics (including collapse studies or buckling characteristics), dynamics and control;
-Modelling of coupled primary and containment systems for the analysis of LOCA accident sequences and passive safety systems response;
-Passive safety systems modelling and experimental investigation (at SIET-ENEA laboratories);
-Internal, hydraulically driven control rod mechanisms, investigated both via numerical simulations and demonstration tests with a scaled facility.
A preliminary test plan will be set up within the year 2004, with some European laboratories to be proposed as hosting facilities for the experimental campaigns, both for scaled and full scale, for component and integral tests.

MARS design
In these last years design and research activities for the MARS reactor have been prosecuted in the Nuclear Engineering and Energy Conversion Department (DINCE) of the University of Rome La Sapienza.
In particular, for MARS it has been studied a decommissioning oriented design due to the adoption of flanged connections in the primary loop.
In the MARS plant decommissioning the adoption of innovative or dedicated techniques or of special equipment is not necessary. In particular, the cutting of large thickness components is not required, thus hugely simplifying the dismounting operations and reducing the wastes.
In addition, the reduced sizes of all components (the biggest ones may be also disassembled in transportable sub-components) makes them easily removable. The general plants simplification allows a huge reduction, up to 50% in comparison with a same size traditional plant, of the number of contaminated or activated components, with a correspondent reduction of the amount of radioactive materials; in addition, the selected structural materials, together with the use of a more clean primary coolant, allows a reduction in total and specific activation of contaminated materials.
Last, but not least, the presence, inside the MARS containment building, of only steel structures (working floors, shields, etc. are made with steel frames) allows to dismount the plant completely, leaving a "clean" building to be reused for other purposes.
Needless to say that contaminated or activated metal pieces may be melted, producing compact wastes ready for storage, while all the clean steel may be reused.
At the Department DINCE special programmes have been elaborated to evaluate the effect of the shape and of the material characteristics of heat exchangers, to evaluate the effect of non-condensable gases on the performances of the atmospheric condenser, as well as the effect of tubes characteristics on heat transfer performances.
A large scale (about 15m height) facility (called NICOLE) has been built at the ENEA research centre of Casaccia to study phenomena related to natural circulation in the primary loop and boiling and condensation in the pool loop. This facility includes the cooling tower and the atmospheric pressure condenser; an experimental campaign focused to analyze main operational conditions of MARS plant, included transients conditions, is being developed.

Research on nuclear space reactor concepts

Small nuclear reactors for space applications (power of about 100 Kwe) are currently under consideration at the Polytechnic of Milano (Dept. of Nuclear Engineering). The aim of this research is to identify the key features nuclear power plants that must be assured in order to be a viable solution for propulsion of rockets or space shuttles and for energy, mainly electricity, production on an extra-terrestrial soil.

A preliminary investigation and design for the latter type of application is underway, within an European Space Agency research contract.

Key requirements to be considered are: limited weight and volume, very high reliability, limited development costs, design and testing of a prototype to be carried out within a small-medium range period (2015).

A LWR, integral configuration, steam or organic cycle option and a HTGR, thermoelectric direct conversion option are being pursued.

The main aspects under evaluation are: core neutronics, also with HEU (highly enriched uranium) fuel option; innovative reactivity control, also exploiting modification of core geometry solutions; plant dynamics and control, both for power levels and for startup and shutdown transients; materials selection; components design; preliminary PSA evaluations.

Moreover, to carry out sensitivity studies on the main design parameters and to identify possible optimum configurations, suitable calculation and simulation codes are under development.

Simulation and Control

A new simulation tool for nuclear reactor dynamics and control is being developed at the Polytechnic of Milano (Dept. of Nuclear Engineering, Dept. of Electronics and Information Technology). The research activity is based on the development of an object-oriented library for nuclear models and components (NUKOMP), to be adopted for the construction of dynamic system simulators with an open source, object-oriented language (MODELICA).

The key features are: modularity, openness, efficiency, code transparency and inheritance.

Preliminary implementations have been performed on the IRIS reactor and on the XADS reactor, thus obtaining fast simulators for the dynamics investigation and for the setting up and testing of different control strategies. The validation is in progress, via comparison with RELAP analyses.

Thermal-hydraulic analyses

The main activities of interest by the thermal-hydraulic group at the DIMNP Department of the University of Pisa concern the following items:

- Uncertainty analysis: continuous upgrading and application of an uncertainty method for application of system thermal-hydraulic codes to the safety analysis of NPPs. This includes application to best estimate transients of PWR, VVER-440 and VVER-1000;
- Coupled containment and primary system calculation;
- Reliability of passive systems with main reference to natural circulation;
- Coupled 3.D neutron kinetics thermal-hydraulic calculations and stability analysis. Application to complex accident in BWR, as for example LBLOCA-DBA and MSIV closure, PWR, as LOFW-ATWS, LBLOCA-DBA and SBLOCA-ATWS, and VVER-1000, as for example LOFW-ATWS and CR-expulsion.
- Assessment of the applicability of RELAP5 to CANDU transients;
- Coupled structure-mechanics thermal-hydraulic calculations in various contexts;
- Accident management of VVER-1000 and development of a model for predicting tube rupture and consequences of tube ruptures in RBMK reactors in the framework of TACIS program. University of Pisa is the main contractor. Other Italian organizations involved in this program are: ENEA and SIET.

Severe accident and containment analysis
Development and validation of codes and models to be used for investigating in-vessel and ex-vessel phenomena during severe accident sequences is under consideration at DIMNP Department of the University of Pisa. Application was made for TMI-2, EPR and VVER-1000, Model development concerned the HPMI, DCH and debris coolability. Experimental analysis was performed for RELAP/SCDAP validation (CORA-13, CORA-W1, PHEBUS-B9, PHEBUS tests, LOFT LP-FP-2)
Containment studies is another item attention of the department is concentrated on. The main research activities refer to: code development and validation of 1-D and 3-D codes, scaling analysis and development and validation of model for steam condensation in presence of non-condensable gases.

3.4 ANSALDO activities

ANSALDO has been involved since 1990 in a wide international cooperation, aiming at studying and comparing several concepts such as the Westinghouse AP600 and the General Electric Simplified BWR. In 1994 the cooperation with Westinghouse led to a common initiative towards a group of European Utilities for setting-up a program in order to evaluate the AP600 passive technology against the European Utilities Requirements (EUR). The initiative was successful and in 1997 the EP1000 (European three-loop version of the AP600) entered its second phase of design aiming at the production by the year 2000 of a Safety Analysis Report to be eventually submitted to European Safety Authorities. As for today, ANSALDO is strictly cooperating with Westinghouse for the design of the AP1000 in the frame of the DOE-sponsored "Near Term Development Program".

AP600 US
The design was awarded the Final Design Approval (FDA) by the United States Nuclear Regulatory Commission (USNRC) in September 1998 and the Design Certification in 1999.

European Passive Plant (EPP)
The Ansaldo Scope is the overall project management and integration together with Westinghouse. The main tasks are the neutron transport analyses, the safety analyses and licensing support, the severe accident analysis, the RCS design transients, the fluid systems design and optimization, the seismic analysis and the accidental releases evaluation.

AP1000 US
The design has been submitted to the USNRC for approval and certification as an updated AP600. The Ansaldo Scope includes the analyses for the licensing process and the extended licensing support, the design transients and functional analyses, the containment system analyses and containment long term pressure and temperature evaluation, the fluid systems design (namely Chilled Water System, Start-up Feed-water System and Heating Ventilation and Air Conditioning systems), the Computational Fluid Dynamic codes analysis to support plant design, the plant layout of the Reactor Building, the piping stress analysis for the primary systems and Class 1/2/3 piping qualification according to ASME Code and considering Leak Before Break approach and effects promoted by external accidental events and the civil structure design, prefabrication and erection, for the Nuclear Island structures.

VVER - Leak Before Break (LBB) Analysis
The project aims to establish a reference leak before break assessment methodology for the main coolant piping (MCP) and the surge line (SL) of the VVER 1000- 320 reactor. The Ansaldo Scope includes the leadership and co-ordination of the Project, a complete re-evaluation of the state of

stress of the MCP and SL, the execution of a complete LBB analysis, based on Russian guidelines, the comparison with western standards and methods, the definition and supervision of a comprehensive material testing program, a proposal for a LBB methodology suitable for the VVER 1000-320 reactor and the evaluation of the Leak detection System.

MEDZAMOR NPP (Armenia): Definition of the new Leak Detection System (LDS) Configuration and application of Leak Before Break (LBB) Methodology to the Primary System and Surge Lines

The project aims both to provide the Medzamor NPP with the technical specification of improved Leak Detection System (LDS) and In-Service Inspection (ISI) procedures and to investigate the applicability of the Leak Before Break. The Ansaldo Scope includes the coverage of standard crack and the final LDS documentation (with partners), the definition of the stratification loads on the surge line, the demonstration of the LBB applicability (with Partners), the verification of piping and support stresses, the seismic stability of main equipment of main coolant loops, the LBB analysis, the input data for plant modifications, the issue of the final report (with Partners) and to obtain the agreement of the safety authorities (with Partners).

Control Systems for Fuel Handling Machines (China)

Delivery of two control systems for VVER 1000 Fuel Handling Machines. The Ansaldo Scope includes the system design, the reliability analysis, the computer-based control system design, the control and power cabinets design, the man-machine interface design, the on-site commissioning, the customer training, the project management, the quality assurance/control and the compliance to russian standards.

Ansaldo is also involved in Heavy Water Reactors (**HWRs**) design and construction (Cernavoda Unit 2) and service (Cernavoda Unit 1). The Cernavoda NPP consists of five 700 MWe CANDU-6 Units, located on the Danube river, 150 km east of Bucharest. In 1991 ANSALDO and AECL (Atomic Energy of Canada Limited), acting in joint venture, were assigned the contract for the completion of Unit 1 by the Romanian National Utility RENEL. The Consortium was in charge of the overall management for erection, commissioning and 18 months initial operation. The ANSALDO scope of supply comprised the Balance of Plant (BOP) including design, equipment procurement and technical assistance for thermal cycle, electrical and auxiliary systems. Components were procured in Italy and in Romania through a technology transfer agreement. Unit 1 was connected to the grid on July 1996 and since then it has supplied about 10% of Romanian electric energy, at an average load factor higher than 87%.
The contract for the completion of Unit 2 became effective in March 2003; the unit is scheduled for full operation by spring 2007.
Service activities on Unit 1 are ongoing.

Completion of Cernavoda Unit 2

Ansaldo acts as the Design Authority for the Balance of Plant (BOP) as member of the Project Management Team, together with AECL and SNN (the Romanian national electric company). The Ansaldo tasks cover home office design activities, equipment supply and technical assistance for thermal cycle, electrical distribution and auxiliary systems. The main supplies are the BOP Digital Control System, Electrical Distribution Equipment (MV switchgears, power centers, motor control centers, transformers, transfer devices) and non-nuclear valves for the entire plant.

Service on Cernavoda Unit 1

Ansaldo has been assigned contracts for the following service activities: optimization of the Recirculating Water System, including the overall process lay-out and mechanical engineering design, specification and procurement of components (new control valves, piping, fittings and

instrumentation), technical assistance to customer for commissioning, subcontracting of a local company for erection, planning of on-site activities prior and during plant outage and project management/supervision; modification of the Feed Water circuit to eliminate fluid-dynamic problems with the introduction of three new check valves; decommissioning cost assessment study to allow the Romanian electric power authority to set up a special fund.